A Study of Properties of Hygroscopic Pyrotechnic Compositions for Inducing Artificial Rainfall

Efim ZASAVITSKY

Gitsu Institute of Electronic Engineering and Nanotechnologies, Academy of Sciences of Moldova, *efim@nano.asm.md*

***Abstract* —A technique developed for studying the efficiency of hygroscopic pyrotechnic compositions that are used to stimulate artificial rainfall is described. The technique is based on a setup for testing the pyrotechnic compositions used to prevent hail. The results of studying the hygroscopic pyrotechnic compounds, such as LOZA-2, which were produced by Stroiproject LTD (Bulgaria) and provided for the research, are presented. It is shown that these hygroscopic pyrotechnic compositions are an effective tool for impacting a cloud environment in order to stimulate the formation of precipitation.**

***Index Terms* — pyrotechnic composition, hygroscopic aerosol, artificial precipitation, aerodynamic stand.**

I. INTRODUCTION

The drought of the last year has shown that the techniques for inducing artificial rainfall are of high priority for Moldova. Works in this field have been purposefully carried out in the world, including former Soviet republics, since the 1960s [1]. At present, in the world there are a few tens of research and operational projects on artificial increase in the amount of precipitation, which are implemented in different countries around the world, i.e., in the United States, Australia, South Africa, China, Morocco, Syria, Saudi Arabia, Mexico, Iran, Cuba, and other countries.

It was found that, in some cases, the amount of extra precipitation induced by seeding the so-called warm clouds is 50% and more. Analysis of the effects of active influences on meteorological processes (weather modification) in the Stavropol Region (Russia) in the past five years has shown that the physical efficiency such operation on the increasing of an artificial precipitation in average is 70%. Economic efficiency of the artificial increasing in precipitation is calculated from the additional croppage of agricultural products produced by artificially precipitated water. Profitability of such operations, depending on the season and the crops is 7+30RUB, that is, for every RUB spent average profit varies from 7 to 30 RUB [2].

In Moldova, these works were conducted in the 1980s. It was shown that an active influence on precipitation forming processes can increase the amount of precipitation by 20-25% compared to the actual norm depending on season [1]. Reagents of two types are used for this purpose: crystallizing materials (solid carbon dioxide, liquid nitrogen, or silver iodide) or hygroscopic particles that intensively absorb water vapor of the respective cloud environment. The results of the recent studies show that, under certain conditions, seeding of cloud environments leads to a change in the microstructure of seeded clouds and, consequently, to an intensification and increase in the amount of precipitation falling from them.

The method of seeding convective clouds with small hygroscopic particles to induce artificial rainfall, which are induced by the combustion of hygroscopic pyrotechnic compositions, was developed and tested at the end of the last century. Despite the encouraging results of application of this method, the question of their physical justification remains open; this in turn requires additional laboratory tests.

II. TECHNIQUE FOR DETERMINING THE EFFICIENCY OF HYGROSCOPIC AEROSOL GENERATORS AND EXPERIMENTAL DATA

At the Gitsu Institute of Electronic Engineering and Nanotechnologies, a setup based on a small aerodynamic stand has been designed and constructed, and a technology for testing the pyrotechnic compositions used in the practice of active impacts for preventing hail has been developed [3, 4]. This setup has been adapted for studying the hygroscopic pyrotechnic compounds (LOZA, Bulgaria) used to induce artificial rainfall.

This aerodynamic stand allows testing any type of pyrotechnic generators of ice-forming aerosols, which are used at present both in operations on protection of agricultural crops from hail damage and in operations (experiments) on modification of precipitation.

It should be noted that the simulation of conditions of the flight of a rocket using an aerodynamic stand is also caused by the fact that the ice-forming activity of aerosols is affected, to different extents, by many factors. One of them is the ratio of the velocity of the generator to the velocity of discharge of a gas-vapor stream from the nozzle of the generator. In addition, the yield of active ice-forming particles heavily and monotonically depends on this parameter.

The aim of this study is to develop a technology for determining the efficiency of hygroscopic generators in an actual temperature interval in operations on modification of precipitation.

Some technical parameters of the used stand areas follows. The diameter of the horizontal aerodynamic tube (HAT) *d* is 330 mm; the length *L* is 9 m. A device for taking ice-forming aerosol samples from the air flow is placed into an Eiffel chamber (*d* = 500 mm, *L* = 3 m). In the front part of the aerodynamic tube, in front of the Eiffel chamber, an access panel is arranged for the installation of full-size generators of ice-forming aerosols and large fragments of samples of pyrotechnical compositions with reagents. The flow velocity (≈30 m/s) in the HAT is determined by the method of measurement of gas dynamic pressure using a "Pitot tube."

For better homogenization and mixing of the aerosol and the air, at a certain distance behind the generator, we installed a special unit, i.e., turbulator intended for the intensive stirring of the aerosol plume in order to obtain a uniform aerosol concentration over the cross section at the sampling point. The estimation of the uniformity of the distribution of aerosol concentration over the cross section showed that the ratio of the concentration at the center to the concentration at any point of the cross section varies within 10%.

The system of sampling and dilution allows representative sampling of the aerosol generated by a generator in the air flow of the HAT. The intake is placed in the Eiffel chamber. The intake consists of a stainless pipe exposed at the center of the tube with holes directed toward the flow, a piping system, and a syringe. Since the difference between atmospheric pressure and dynamic pressure is usually no more than 1%, the transfer of the sample from the tract of the aerodynamic tube into a mixing chamber is carried out isothermally and with a constant humidity.

To prevent the suppression of the activity of forming particles owing to the effect of "re-seeding", it is necessary to obtain an optimum concentration of crystals in the mixing chamber, which would provide a statistically significant result of the experiment. In order to reduce the aerosol concentration, the sample had previously been dissolved in a cube with a volume of 1000 and 125 l, respectively.

The nucleation and growth of water drop crystals occurs in a fog produced in the working volume of the mixing chamber. In the capacity of a mixing chamber in the stand under discussion, we used an ILKA KTLK-1250 climate chamber with a working volume of 1200 l modified as follows.

- Access holes were made in the door for the placing and removal of microthermostats.
- A system for introducing a measured sample of the active aerosol into the working volume was prepared.
- A fan to mix the air to reduce temperature gradients was installed in the working volume.
- A temperature and humidity sensor was installed.
- In the upper part of the cloud chamber, a lighting unit was installed; it generated a beam of light for the visual observation of the process of formation of fog, variation in its density, and formation of ice crystals.

Fog in the chamber is created by the injection of hot vapor, which condenses to form water aerosol with a modal diameter of droplets of about 4 μm.

Given the linear dimensions of the chamber, the vertical temperature gradient in the chamber does not exceed 0.02 deg/cm; the horizontal gradient, 0.005 deg/cm.

The initial water content of fog depends on the duration of the introduction of vapor; it was 0.4-3.0 g/m^3.

The accuracy of temperature measurement in the chamber working volume is ±0.1^{o}C.

For the experiment (measurement) temperature, we take the temperature settled in the chamber working volume after the formation of fog in it, before the introduction of the aerosol sample.

The lifetime of vapor fog in the chamber for an initial water content of 1÷2 g/m^3 is 2÷3 min.

Fog in the cloud chamber is generated by the condensation of a hot water vapor being introduced into a cooled volume.

Water drops that are formed on introduced nuclei grow to sedimentation sizes and are recorded at the bottom of the chamber using a thermostat. The quantity of the microthermostats is determined by objectives of the specific experiment. According to the number of crystals formed, knowing the characteristics of the equipment and consumption data for the generator, we can calculate the yield of nuclei.

The duration of one measurement (experiment) using the aerodynamic stand, which consists in the measurement of the yield of active ice-forming particles, is 30-40 min at a given temperature.

For the determination of the yield of active water drops forming particles according to this technique, it is necessary to take into account a number of factors, the disregard of which can significantly distort the results:

- the presence of significant temperature gradients in the chamber working volume;
- inhomogeneity of the water content of fog;
- run-to-run reproducibility of fog parameters;
- local supersaturation of water vapor upon the introduction of the aerosol in the chamber;
- coagulation of aerosol particles in the process of formation and introduction into the chamber, their precipitation on the chamber walls, injector, and feeding hoses.

The estimation of accidental errors of measurements showed that the error of a single measurement is ±15% in a temperature range of –10 to 20^{o}C. As the temperature decreases, the error is reduced. The total systematic error is ±3% and can be ignored in the calculations.

Based on the designed aerodynamic stand and the developed procedure for testing hygroscopic compositions, we carried out experiments on the determination of the practical yield of active particles of a hygroscopic composition produced by the Stroiproject LTD (Bulgaria). Figure 1 shows some samples of these hygroscopic agents made in the form of reagent sticks.

Experimental studies of these hygroscopic pyrotechnic compositions were performed as follows. We used two versions of the tests: in a dynamic mode, which involves the combustion of entire hygroscopic pyrotechnic sticks in the aerodynamic tunnel, and in a static mode, in which weighted portions of a hygroscopic pyrotechnic composition are combusted in a special generator.

Fig.1. Samples of hygroscopic agents made in the form of reagent sticks.

After dilution of the resulting aerosol with an air medium in the working volume, a sample of this aerosol was introduced into in a preliminary prepared cloud chamber. The preparation of the chamber consisted in the creation of a model environment, which had the parameters similar to real cloud entities and exhibited an appropriate temperature (T = 4–15°C) and humidity (0.4–3 g/m^3).

The sedimented droplets of moisture were studied under a microscope capable of magnification up to 150 times. The obtained distribution pattern of water droplets was visually studied and electronically stored using a special video camera (Figs. 2, 3).

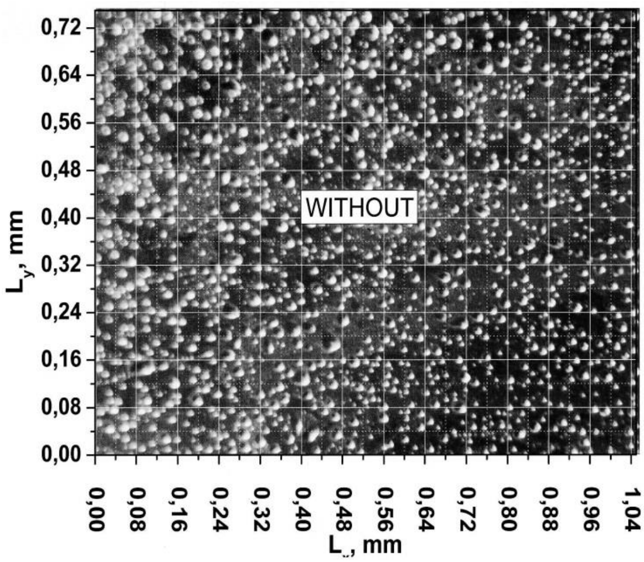

Fig. 2. Distribution of droplets of the model air medium obtained via sedimentation on the surface of microcryostats before the introduction of a hygroscopic agent into the cloud chamber.

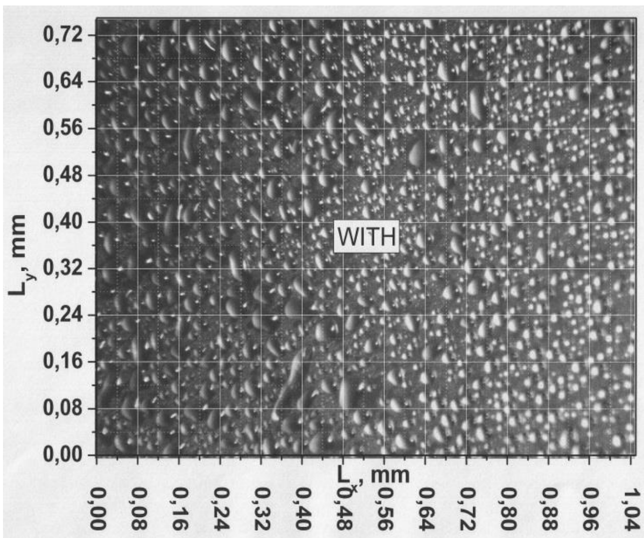

Fig. 3. Distribution of droplets of the model air medium obtained via sedimentation on the surface of microcryostats after the introduction of a hygroscopic agent into the cloud chamber.

After that, the derived information was analyzed with respect to the size distribution of water droplets before and after the introduction of a hygroscopic pyrotechnic composition. The used parameters were the temperature and water content of the model cloud environment with the values from the above given range for these parameters.

The studies in a wide temperature range (−15 to +10°C) on the developed setup for testing hygroscopic pyrotechnic compositions (LOZA, Bulgaria), which are used in the practice of inducing artificial rainfall, showed that this the pyrotechnic composition is not efficient for using as an ice-forming agent in the range of negative temperatures (−15 to −6°C, $N < 10^9$ g^{-1}) for impacting the supercooled clouds.

A qualitative analysis of this pyrotechnic composition shows that it can be used to induce artificial rainfall in the range of positive temperatures (0 to +10°C) for impacting the warm clouds: a comparison of the distribution of droplets with and without the hygroscopic pyrotechnic composition (LOZA, Bulgaria) shows that the introduction of the pyrotechnic composition into the cloud chamber leads to a significant increase in the size of the resulting droplets (more than twofold).

III. CONCLUSIONS

Thus, the studies of hygroscopic pyrotechnic compositions (LOZA, Bulgaria) have shown that their combustion at positive temperatures leads to the generation of active centers with high hygroscopic properties, which can be used for impacting the so-called warm clouds in order to induce artificial rainfall.

REFERENCES

[1] Активное воздействие на градовые процессы в Молдове / Противоградовая Служба; Кишинев: 2004. – 300с

[2] **http://www.stvs-hail.ru/osadki.htm**

[3] Zasavitsky E.A. The aerodynamic stand for research of ice-forming characteristics of reagents. *Moldavian Journal of the Physical Sciences.* 2010, **9**(2), 237-242.

[4] Zasavitsky, E.; Kantser, V.; Sidorenko, A.; Garaba, I.; Potapov, E.; Kim, N. Effect of time on the properties of crystallization agents: ice-forming aerosols. In: *Novel Nanomaterials for Electronic, Photonic and Biomedical Application*s: ICNBME-2011, Intern. Conf. on Nanotechnologies and Biomedical Engineering, German-Moldovan Workshop on Chisinau, Republic of Moldova, 7-8 July 2011: Proceedings. Ch., 2011, p. 117-120.